

CLAIMS

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- 5 1. A Seismic detection apparatus comprising:
a first, second and third receiver, each of the receivers
spaced within a plane; and
a fourth receiver located external to the plane thereby
enclosing a selected volume bounded by the first, second,
10 third and fourth receivers over which measurement of seismic
signals occurs.
- 15 2. A seismic detection apparatus according to claim 1
wherein the receivers comprise geophones.
3. A seismic detection apparatus according to claim 1
wherein the receivers comprise hydrophones.
- 20 4. A seismic detection apparatus according to claim 2,
wherein the receivers comprise accelerometers.
- 25 5. A seismic detection apparatus according to claim 2,
wherein the seismic detector is adapted to detect seismic signals
along three mutually orthogonal axes.
- 30 6. A seismic detection apparatus according to claim 1,
wherein the receivers are spaced to form a tetrahedron, with three
receivers spaced to define a triangle within the plane and a fourth
receiver placed external the plane but in line with the centroid of
the triangle.
7. A seismic detection apparatus according to claim 2,
further comprising a processor adapted and configured to analyze

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detected seismic components from individual receivers to separate P-wave components from S-wave components.

8. A seismic detection apparatus according to claim 7,
5 wherein the processor is provided at substantially the same location as the receivers so as to allow for on-site processing.

9. A seismic detection apparatus according to claim 7,
10 wherein the processor is provided in a location remote from the receiver so as to allow off-site processing of detected seismic components.

10. A seismic detection apparatus according to claim 1,
15 wherein the receivers are adapted to detect components along one axis and orientation of the receivers is selected so as to permit processing of one-component data to identify P-wave components within the plurality of seismic components.

11. A seismic detection apparatus according to claim 1,
20 wherein the spacing of the receivers is selected to be smaller than the wavelength of the detected seismic components.

12. A seismic detection apparatus according to claim 1, when
25 attached to a wireline for placing temporarily downhole.

30 13. An apparatus for hydrocarbon exploration comprising:
a seismic source adapted to impart seismic energy into the earth at a predetermined time;
at least three seismic receivers each adapted to measuring the seismic energy from the seismic source that has been reflected from one or more subterranean earth structures outside the near-site structure, the seismic receivers located substantially in a plane at or near the earth surface, wherein

said at least three seismic receivers are spaced less than about 1 meter from each other to form a receiver cluster.

14. An apparatus according to claim 13 further comprising a fourth seismic receiver located less than about 1 meter from the at least three seismic receivers and wherein each of the receivers are one-component geophones.

15. An apparatus according to claim 14 wherein the each of the one-component geophones are positioned in a diamond-shaped pattern and each of the sensed components are in different directions within the plane.

16. An apparatus according to claim 13 wherein each of the receivers are geophones capable of measuring at least three components.

17. An apparatus according to claim 16 wherein the earth surface is the surface of land.

18. An apparatus according to claim 16 wherein the earth surface is the sea bottom.

19. An apparatus according to claim 13 wherein a hydrocarbon reservoir is located near the one or more subterranean earth structures outside the near-site structure.

20. An apparatus according to claim 16, wherein the at least three components of each of the geophones are transmitted to a processing unit to calculate an approximation of the full wavefield at the position of the cluster making use of a free surface boundary condition.

21. A method for hydrocarbon exploration comprising:
imparting seismic energy into the earth at a predetermined
time such that the seismic energy travels through the earth and
reflects off of one or more subterranean earth structures outside
5 the near-site structure;

positioning at least three seismic receivers
substantially in a plane at or near the earth surface, wherein
the seismic receivers are spaced less than about 1 meter from
each other to form a receiver cluster;

10 receiving seismic energy imparted by the seismic source
that has been reflected off of the one or more subterranean
earth structures;

storing seismic data that represents the received seismic
energy; and

15 analyzing the data such that characteristics of one or
more hydrocarbon reservoirs can be determined.

22. A method according to claim 21 wherein the step of
analyzing comprises the step of measuring the curl and divergence
20 of the wavefield from the seismic data, thereby identifying seismic
components within the seismic data.

23. A method according to claim 22, wherein P-wave and S-wave
components are separately identified.

25 24. A method according to claim 23, wherein up-going and
down-going wavefield components are identified from the seismic
data.

30 25. A method according to claim 24, wherein the step of
analyzing further comprises attenuating unwanted seismic components
from seismic data.

26. A method according to claim 25, wherein the step of analyzing further comprises the step of averaging the curl and divergence over the selected plane or volume of acquisition.

5 27. A method according to claim 26, wherein the step of analyzing further comprises the step of defining the selected plane or volume of acquisition to be small compared to the wavelength of seismic waves to be detected.

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